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SPIN TESTS; METHOD OF DATA PRESENTATION /1*

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ABSTRACT. The method of data presentation for wind tunnel spin tests, used by the Lille Institute of Fluid Dynamics, is described with classification of spin types and spin recovery, influence of control surface setting on spin recovery, nomenclature and symbols used, and application of wind tunnel data to full-scale aircraft.

This paper describes the method used by the Institute of Fluid Mechanics of Lille for presenting results of aircraft spin tests. The conventions given are valid simultaneously for flight tests and for wind tunnel tests. The paper is arranged in accordance with the following layout:

1. Terminology and Notations
2. Presentation of Data on Stationary Spin
3. Classification of Stationary Spins
4. Presentation of Data on Recovery from Spin
5. Classification of Recovery from Spin.

1. Terminology and Notations /2

The characteristics of spin, given here, always correspond to a left-hand spin; the so-called left-hand spin is a spin in which the left wing is high.

For the rudder and the ailerons, the term "with" or inward is used to indicate that these control surfaces are deflected as they would be for a turn in the same direction as the spin. For deflections in the opposite sense, we will use the term "against" or outward.

The expression "raised elevator" designates the position corresponding to the pulled stick, whether in inverted or normal spin, so as to have a unique denomination for a given position of the control surface with respect to the aircraft.

A spin is called slow or rapid depending on whether the speed of rotation is low or high.

All numerical values are given for the full-scale aircraft.

The notations used are as follows:

* Numbers given in the margin indicate pagination in the original foreign text.

a) The longitudinal trim is determined by the modulus of the angle made by the fuselage axis with the horizontal plane; thus, it always ranges between 0° and $+90^{\circ}$ (according to general convention, this trim would always be negative in a spin).

b) The lateral trim is counted as positive if the right wing is below the horizontal of the center of gravity, whether the spin is normal or inverted. In this manner, when in a normal spin, the lateral trim will remain in the neighborhood of 0°, being sometimes positive and sometimes negative; in an inverted spin, its modulus will be close to 180° (below or equal to 180°), being sometimes positive and sometimes negative.

c) The relative course is the angle between the radius of spin and the horizontal projection of the front portion of the fuselage axis; this course is counted positive if the spin axis is on the same side as the turn axis in a turn of the same direction.

d) The incidence i (Standard X-02-105) is positive if the wind is from below. /3

e) The sideslip j (Standard X-02-105) is positive if the wind is from the left of the pilot.

2. Presentation of Data on Stationary Spin

Tables consisting of 12 sectors are used for presenting the results; these 12 boxes correspond to 12 combinations of three aileron deflections and of four elevator deflections; these tables are arranged as given below.

Elevator raised Ailerons outward	Elevator raised Ailerons neutral	Elevator raised Ailerons inward
Elevator half-raised Ailerons outward	Elevator half-raised Ailerons neutral	Elevator half-raised Ailerons inward
Elevator neutral Ailerons outward	Elevator neutral Ailerons neutral	Elevator neutral Ailerons inward
Elevator low Ailerons outward	Elevator low Ailerons neutral	Elevator low Ailerons inward

Each portion of the table is again subdivided into boxes giving the characteristics of the spin, as indicated in the grid given below.

In the right-hand box of the first row, the letter F indicates that a film had been taken.

3. Classification of Stationary Spins

The box "character of spin", corresponding to each test, contains one or

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Number of test	Test filmed or not	
Character of spin	Number of turns observed	
Longitudinal trim	Lateral trim	
Duration of one turn (sec)	Relative course	
Radius of spin (m)	Rate of descent (m/sec)	Descent per turn (m)

several letters symbolizing the character of the observed phenomenon; these symbols are as follows:

Stationary spins	permanent spin	A
	quasi-permanent spin	AE
	oscillatory spin	B
	highly oscillatory spin	BE
Quasi-stationary spin		C
Unstable spin		D
Highly unstable spin		DE
No spin	slight turn	E
	no turn at all	EE

The spin is permanent (A) when its various characteristics remain practically unchanged in time.

A spin is quasi-permanent (AE) when one or several characteristics vary slightly in time, in a manner which is neither continuous nor regular.

A spin is oscillatory (B) when one or several characteristics vary con- /5
tinually at moderate amplitudes (the symbols contained in the other boxes show whether the oscillation is periodic or not).

A spin is highly oscillatory (BE) when one or several characteristics vary at high amplitudes, for example when the amplitude of the longitudinal trim exceeds $\pm 10^{\circ}$.

A spin is quasi-stationary (C) when, during an arbitrary number of turns, none of the characteristics vary constantly in the same direction but the stationary spin nevertheless stops by itself.

A spin is unstable (D) when one or several characteristics vary slowly, always in the same direction on the average, which leads to recovery from the spin after more than four spinning turns.

A spin is highly unstable (DE) when, as in the case of unstable spin (D), one or several characteristics vary on the average, always in the same direction but at a sufficiently high rate to cause spin recovery after less than four turns but after more than two.

The case in which there is no spin or in which the aircraft executes only a slight turn (E) is the case in which the aircraft, after having gone into a spin, immediately recovers from the spin within at most two turns.

The case in which there is no spin and in which no turn takes place (EE) is the case in which, to a test of entry into spin there corresponds a dive without rotation.

The letter T indicates that the movement degenerates into autorotation, i.e., a rotation about an axis close to the fuselage axis. The symbol TD indicates that this roll is unstable.

The letter V means that the vertical axis, about which the aircraft spins, is displaced in space in a disordered manner by about one or two spans per spinning turn.

In the boxes containing the numerical values, the following symbols are used to give an indication of the variation in the quantity involved: /6

$\longrightarrow$	stationary,
no indication	quasi-stationary,
$\wedge$	varies irregularly in a moderate manner,
$\hat{\wedge}$	varies irregularly at large amplitudes,
$\wedge\wedge$	varies in a highly irregular manner,
$\sim$	varies periodically at moderate amplitude,
$\approx$	varies periodically at large amplitude,
$\sim\!\!\sim$	varies quasi-periodically,
$\nearrow$	increases slowly,
$\Nearrow$	increases rapidly,
$\searrow$	decreases slowly,
$\Searrow$	decreases rapidly.

4. Presentation of Data on Recovery from Spin

The description of each test for spin recovery is given by entering the values of the various characteristics in a grid laid out as given below.

In the box "type of evolution" the symbols defined in Section 5 are entered.

In the box "number of turns observed", the symbol > preceding the entered numeral means that, at the end of observation, rotation had not yet stopped. /7

δ	Deflection of Fin Before	Deflection of Fin After	β	Deflection of Elevator Before	Deflection of Elevator After		Other Maneuvers
α	Deflection of Ailerons Before	Deflection of Ailerons After	β_E	Trimming of Fixed Surface Before	Trimming of Fixed Surface After		

Type of evolution	Longitudinal trim	Duration of one turn	Radius
Number of turns observed	Lateral trim	Rate of descent	Other characteristic

The six other boxes describe the phenomenon itself; each of these is subdivided into three equal portions. This graduation permits giving indications on the evolution of the phenomenon as a function of the time required for observation.

The symbols used for describing the variations of each individual quantity are the same as those used for the spins themselves.

The descriptions of tests on spin recovery are grouped in tables of five tests; the tests described in a given table always correspond to the same initial spin.

5. Classification of Recovery from Spin

In the box "type of evolution" of the table given in Section 4, one or several letters are entered that symbolize the character of the phenomenon observed; these symbols are as follows:

Lateral recovery in turn	K
Lateral rectilinear recovery	KE
Oblique recovery in steep spiral	L
Oblique recovery without rotation	LE
Vertical recovery in vertical roll	M
Vertical recovery without rotation	ME
Change to inverted flight	N
Recovery with change to inverted flight and stopped rotation	NE
Continued spin	O
After stopping, a new spin starts	P

Lateral Recovery in Turn: K

The aircraft rapidly moves away from the axis of spin and the rotation is braked. During this type of spin recovery, the rate of descent does not increase and only a horizontal component which increases rapidly is added. In general, the longitudinal trim does not increase much after the moment at which the radius commences to increase rapidly and at which the rotation begins to stop. This type of spin recovery is accompanied by a considerable raising of /8
the leading wing, which gives the aspect of a turn to the end of the evolution. These recoveries lead to the shortest restoration and, for this reason, are the most desirable types.

Lateral Rectilinear Recovery: KE

The differences from the preceding type of recovery include: the horizontal velocity increases more slowly; the attitude reached is generally less of the nose-dive type; the span is horizontal or the leading wing is low.

This type of spin recovery frequently entrains the risk of a new entry into spin.

Oblique Recovery in Steep Spiral: L

The spin develops further and changes into a nose-down spiral; the rotation continues; the attitude becomes more of the nose-down type but not exactly vertical; the radius increases; the rate of descent increases notably and rapidly; the normal acceleration increases regularly and becomes considerable; restoration consecutive to such a recovery is long.

Oblique Recovery with Stoppage of Rotation: LE

The modulus of the longitudinal trim increases; the rotation stops; the radius increases slightly; the aircraft moves slowly away from the axis of spin, with its span almost horizontal; the rate of descent increases but less than in the preceding type of recovery; restoration is less long.

Vertical Recovery in Vertical Roll: M

The aircraft goes into a dive while the rotation continues, with the fuselage becoming almost vertical; the radius varies little or diminishes; the rate of descent increases considerably and rapidly, with the normal acceleration remaining weak; restoration is long.

Vertical Recovery with Stoppage of Rotation: ME /9

The aircraft goes into a dive often with one wing lower and the wing-fuselage plane becoming almost vertical; the rotation stops, frequently abruptly at the end of evolution; the rate of descent increases, with the normal acceleration being low; restoration is long.

Change to Inverted Flight: N

The aircraft goes into a dive and changes to inverted flight; the rotation continues.

Recovery with Change to Inverted Flight and Stopped Rotation: NE

The beginning of the evolution is quite similar to that of the vertical recovery with stoppage of rotation; frequently, the rotation stops abruptly only at the moment at which the aircraft turns upside down; passage to inverted flight itself often is abrupt.

Continued Spin: O

The maneuver performed for recovering from the spin can lead only to a modification of the spin.

After Stopping, a New Spin Starts: P

At the end of a spin recovery, the aircraft is in such a position that a new spin starts immediately.

Following the letter B, the index g means a new spin in the same direction as the initial spin, while the index d means a start in the opposite direction; if no index is given, the direction of the new spin is undetermined.

In the above classification, no provision is made for the duration of spin recovery, which is due to the fact that these recoveries can take place just as well in ten turns as in less than a quarter turn, for example.

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